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ABSTRACT

The purposes of the assessment project were to determine when the fourth grade math skills were acquired by the majority of students in the Salem, Oregon public schools, and to compare accomplishment on the criterion-referenced test with accomplishment on a standardized test. Because the project required testing grades 3-6, multiple matrix sampling was used. Five subtests were constructed for each type of test. The results showed that the students were behind in their math skills. But with persistent effort, the majority of students could acquire the basic skills. For grades 3 and 4, the standardized test was an easier test. (Author)

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DISTRICT-WIDE EVALUATION OF MATH COMPUTATION SKILLS

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INTRODUCTION

From about 1969 there appears to have been a consistent decline in the mathematics skills of Salem students. Teachers at all levels have complained that students could not perform basic computational problems. Students have been entering class totally unprepared. The objectives of the course could not be met because teachers have been forced to step back and reteach basic math skills. This complaint of poor skills has been reinforced by district average test scores. Since 1969, Salem's average scores on the Metropolitan Computation Achievement Test declined.

The cause for this decline in basic mathematical knowledge has been disputed and probably will be for some time to come. Some have placed the blame entirely on modern mathematics. Others contend that the blame belongs on teachers and their lack of emphasizing the role of mathematics in society and the students' need to achieve these mathematics skills.

During the Spring of 1972 and 1973, a group of teachers in Salem met to examine and to define some basic math skills that students should acquire and to establish approximately when in a child's school career these should be acquired. The Committee's work has since been published and distributed to Salem teachers for review and eventually for implementation into the curriculum. To help determine whether or not a student can perform the expected math skills, test questions were developed and to date, have gone through one revision.

As it now stands, 285 expectancies and more than 1,425 test questions have been developed by the Math Expectancy Committee. Student tracking cards have also been developed to go along with the expectancies as a management aid for teacher charting of student progress on the expectancies.

The sheer number of expectancies, test questions and students makes assessment of district-level accomplishment extremely time-consuming and complicated. To keep the amount of time, number of people and number of questions at a minimum, sampling procedures were used. The procedure used was similar to that in assessing the phonic skills. This procedure was multiple matrix sampling. Matrix sampling, as it is commonly called, involves building a specified number of smaller tests from the total group of questions. These smaller tests are then given to a sample of the total group of students. Estimated scores are calculated as if all the students had taken every question.

PURPOSE

This year's assessment on the Salem Math Expectancies had a twofold purpose. First was to determine when the skills defined by the fourth grade expectancies were actually acquired. Second was to compare accomplishment on the Salem Math Expectancies with accomplishment on the computation subtest of the Metropolitan Achievement Test (MAT).

PROCEDURES AND RATIONALE

The total number of math expectancies and accompanying test questions are formidable. Therefore, for this pilot assessment a streamlining procedure had to be developed so that preliminary assessment would cause minimum disruption of the normal classroom activities. The Math Specialist and the Supervisor for Evaluation and Program Audit selected the fourth grade for the pilot assessment because by the end of the fourth grade, all of the basic mathematics skills (addition, subtraction, multiplication and division) have been introduced or should have been introduced if normal growth occurred. The measuring of these basic skills at this time appeared

to be ideal to test the expectancy. Along with the skill, the Math Committee set criterion levels that students were expected to achieve.

Since part of the pilot evaluation process was to identify whether a discrepancy existed between the desired level set by the expectancies and when the objectives were actually accomplished, the evaluation design called for the testing of students in grades three, four, five and six.

Additionally, the students were tested on the Metropolitan Achievement Test - Computation. This is a national standardized achievement test. The Elementary II level (grades 3.0 to 4.9) was given to the same students that took the expectancy tests.

The Math Expectancy Tests and the Metropolitan Achievement Test - Computation were examined for comparability. They were found to be testing virtually the same objectives. The only difference was that none of the test questions on the MAT tested divisions of three digit dividends by one digit divisors. There were six problems dealing with that skill on the Math Expectancy Test. The MAT test contained two questions that required students know-how to add fractions. This skill was not tested by the pilot Math Expectancy Test. However, in the majority of mathematics textbooks, this skill is introduced at the fourth grade level. Therefore, these two problems were left in the test.

Because of the limited number of problems for each math expectancy (5), the 12 math expectancies tested were grouped under four major headings - addition skills, subtraction skills, multiplication skills and division skills. Appendix A contains all of the fourth grade Math Expectancies. Those with an asterisk are the ones used in the pilot assessment.

There was a total of 70 questions in the Math Expectancy assessment and 40 questions on the MAT - Computation Test. The 70 Math Expectancy questions were divided into five subtests, each containing 14 test questions. The MAT - Computation Test containing 40 questions was divided into five subtests, with eight questions in each. Both sets of subtests were numbered from one through five and color coded. This was done for ease in handling of data. Both subtests #1 were printed on yellow paper, subtests #2 on green paper, and so on. Each child participating in the pilot assessment took two tests. The first was the Math Expectancy Test and the second was the MAT - Computation Test. The child took the same color of test both times.

A total of 100 students per grade was tested. This meant that 20 students per grade level took each subtest. Therefore, a grand total of 400 students were tested in grades three through six.

Table 1 shows the breakdown by major skill area for each test. The table shows that the tests are, practically speaking, perfectly balanced according to areas of emphasis in terms of percent of questions in a particular skill area.

The total amount of time to give both tests did not exceed 30 minutes and extended over a two-day period.

TABLE 1

Comparison of Skill Emphasis Between
Salem Math Expectancy Test and MAT-Computation Test
By Number of Questions and Percent of Questions

	ADDITION		SUBTRACTION		MULTIPLICATION		DIVISION		TOTAL
TEST	No.	%	No.	%	No.	%	No.	%	Number
Math Expectancy Level 4	19	27	20	29	18	26	13	19	70
MAT Computation 3.0 to 4.9	12	30	12	30	9	23	7	18	40
TOTAL	31	28	32	29	27	25	20	18	110

The results of the pilot assessment will be reported in three phases. Phase One explains the results on the Math Expectancy Test; Phase Two, the results of the MAT - Computation Test and; Phase Three reviews the tests jointly. The emphasis in Phase Three is on the similarity of the results for the two tests.

Math Expectancy Test

Table 2 contains the summary results of the Math Expectancy Test for grades three through six. The average criterion score for the objectives tested was 74 percent. As can be seen from Table 2 Column 3, it is not until the very end of fifth grade - first part of sixth grade that the students reach criterion. A more detailed analysis later on in this report will show that this is a false picture of overall ability and that the majority of major skills are not acquired until the sixth grade.

TABLE 2

Results of Spring 1975 Testing
Pilot of Level 4 Math Expectancies
Average Scores and Middle Sixty-seven percent Range Scores

GRADE	AVERAGE*	AVERAGE %	RANGE SCORE*	RANGE %	STANDARD DEVIATION*
3	23	33	9-37	13-53	14
4	41	59	23-59	33-84	18
5	51	73	33-69	47-99	18
6	59	84	46-70	66-100	13

N = 70
* Raw Scores

An analysis of the second half of Table 2 reveals that if given the opportunity and the needed instruction, students, over time, will acquire the basic skills. The range scores reported in Table 2 are the scores between which the middle 67 percent of the students would fall. This means that approximately 16 percent of the students scored higher than the top score reported and 16 percent scored below the lowest score reported. To calculate the range scores, subtract the standard deviation (the score in the last column of Table 2) from the average score. This gives the lower limit score in the range. Next, add the same deviation score to the average score, thus calculating the upper limit of the range. Between the range scores lies 67 percent of the students taking the test.

Range scores are valuable in analyzing an instructional program particularly when the skills are held constant and the amount of time spent on learning the skills can vary according to student needs. From an examination of the last three columns in Table 2, it appears that not until the end of the sixth grade do students' scores begin to cluster tightly around the average score. We do see from year to year that there is an increase in the average score. The major problem is that the standard deviation between grades four and five remained constant, showing that those students who were doing well continued to do well and those doing poorly did not move substantially closer to the average score. The distance from the average of low student scores remained constant but there was improvement in their math skills. Between the end of fifth grade and the end of the sixth grade, not only did the average score increase, but the standard deviation decreased signaling a good growth in the abilities of low-achieving students. That is, by the end of the sixth grade, the scores of the low students were closer to the average score of the entire group.

Table 3 shows a breakdown of the Math Expectancy Test results by the four major objectives. The Table contains the average percent of the questions correct for each objective by grade level; the criterion score set by the Committee; and the number of test questions related to the objective.

Except for meeting the addition objective by grade five, the average student accomplishment did not meet or exceed the criterion score on all other objectives until sometime during the sixth grade. Based upon the criteria scores established by the Committee, Salem elementary students on the average are a year or more behind in achievement on the Salem Math Expectancies, Level 4.

TABLE 3

Analysis of Student Accomplishment of
Salem Math Expectancies Level 4
By Major Skills

OBJECTIVE	GRADE	PERCENT CORRECT	CRITERION SCORE	NO. OF ITEMS
Add two 1-6 and four 1-3 place numbers	3 4 5 6	59 75 83 88	80%	19
Subtract any 1-4 place real numbers with regrouping	3 4 5 6	40 69 73 86	80%	20
Multiply 4 digits by 1 digit; 2 digits by 10's and 2 digits by 2 digits	3 4 5 6	11 48 68 80	73%	18
Divide 2 digits by 1 digit; 3 digits by 1 digit	3 4 5 6	14 36 64 83	70%	13
TOTAL	400	**********	74%	70

MAT - Computation Test

In order to assist in the validation process, additional testing beyond the Math Expectancy Test was conducted. The test chosen for this purpose was the Computation section of the Metropolitan Achievement Test. Until the 1974-75 school year, this test was administered district-wide. It has since been replaced by the Iowa Test of Basic Skills.

Table 4 contains a summary of the scores for each grade level. Two additional pieces of information have been added - percentile rank scores and grade equivalent scores. The summary data presented in Table 4 parallels that presented in Table 2 for the Math Expectancy Test.

If the same criterion score for overall accomplishment is used (74 percent correct), mastery of the skills occurs by the end of fifth grade. A further analysis of these grade level summary scores reveals a more consistent narrowing of the range score. This is not an unusual happening. The MAT - Computation Test is a third-fourth grade test. Therefore, one would expect such a decrease in the distance that the scores varied from the average. The point that must be made here is that the largest decline in the standard deviation occurred between fifth and sixth grades. The same place that it occurred on the Math Expectancy Test.

The narrowing of the range score must not be interpreted to mean that the complete ability range is not wider at sixth grade than it was at fourth grade. The ability spread is greater at sixth grade than at fourth grade when more than fourth grade skills are being measured. (See 1974-75 Standardized Test Report). The point being made is: If the skills and the difficulty of the problems are kept constant, students are able to acquire the basic skills over time.

TABLE 4

Results of Spring 1975 Testing
MAT-Computation Test Elementary II
For Grades 3 and 4
Average Scores and Middle Sixty-seven Percent Range Scores

GRADE	AVERAGE*	AVERAGE PERCENT	RANGE SCORE*	RANGE PERCENT	PERCENTILE RANK	GRADE EQUIVALENT	STANDARD DEVIATION*
3	22	55	11-31	28-78	50	3.8	9
4	28	70	20-36	50-90	32	4.4	8
5	32	80	25-39	63-98	52 **	5.1	7
6	35	87	31-39	78-98	77 **	5.9	4

N = 40

* Raw Scores

** These fifth and sixth grade students have been compared to fourth grade students.

Table 5 shows the average percent of students answering the questions correctly for each objective by grade level. Except for division, the MAT - Computation Test shows that on the average Salem students acquire fourth grade basic skills by the end of fifth grade. This is a year behind what would be expected. Division skills, according to test results, are not acquired until the end of the sixth grade.

TABLE 5

Analysis of Student Accomplishment of
MAT-Computation Test Elementary II
By Major Skills

OBJECTIVE	GRADE	PERCENT CORRECT	CRITERION SCORE	NO. OF ITEMS
Add two 1-6 and four 1-3 place numbers	3 4 5 6	70 82 86 92	80%	12
Subtract any 1-4 place real numbers with regrouping	3 4 5 6	61 73 84 90	80%	12
Multiply 4 digits by 1 digit; 2 digits by 10's and 2 digits by 2 digits regrouping	3 4 5 6	47 66 79 91	73%	9
Divide 2 digits by 1 digit; 3 digits by 1 digit *	3 4 5 6	35 51 68 77	70%	7
TOTAL	400	**********	74%	40

* MAT - Computation Test only tests the first part of the objective - division of two digits by one digit.

Comparison of the Two Tests

The two tests, MAT - Computation and Math Expectancy, compliment each other. The tests were testing the same skills in much the same form. A review of Table 6 below shows that the MAT - Computation Test is an easier test for third and fourth graders. However, by the end of sixth grade, the percent of questions answered correctly is virtually the same.

TABLE 6

Comparison of Summary Scores On
MAT-Computation and Math Expectancy Tests

GRADE	AVERAGE PERCENT		RANGE PERCENT	
	MAT-Computation	Math Expectancy	MAT-Computation	Math Expectancy
3	55	33	28-78	13-53
4	70	59	50-90	33-84
5	80	73	63-98	47-99
6	87	84	78-98	66-100

Table 7 and Graphs 1-4 show a comparison of test results by major skill for each grade level. These comparisons show the internal consistencies within the two tests. The major differences in the percent of questions correct per skill occurs in the third and fourth grades. It is the Salem Math Expectancy questions which are the most difficult. Two explanations are possible and both have some bearing on the differences. First, the MAT - Computation Test is a multiple choice test and therefore, guessing becomes a minor factor. The second factor affecting the differences at these two levels is the design of the tests. The Math Expectancies were designed for fourth grade students. The test questions, if constructed properly, would be too difficult for all but the most advanced third graders.

TABLE 7

Comparison of Math Expectancies and
MAT-Computation Scores By Objective
Percent Correct

OBJECTIVE	GRADE	MATH EXPECTANCY SCORES		MAT SCORES	
		% Correct	Possible Score	% Correct	Possible Score
Add two 1-6 and four 1-3 place numbers - 80% accuracy	3	59	19	70	12
	4	75		82	
	5	83		86	
	6	88		92	
Subtract any 1-4 place real numbers with regrouping - 80% accuracy	3	40	20	61	12
	4	69		73	
	5	73		84	
	6	86		90	
Multiply 4 digits by 1 digit; 2 digits by 10's and 2 digits by 2 digits regrouping - 73% accuracy	3	11	18	47	9
	4	48		66	
	5	68		79	
	6	80		91	
Divide 2 digits by 1 digit and 3 digits by 1 digit - 70% accuracy *	3	14	13	35	7
	4	36		51	
	5	64		68	
	6	83		77	
TOTAL	400	********** ********** **********	70	********* ********* *********	40

* MAT - Computation Test only tests the first part of the objectives - division of two digits by one digit.

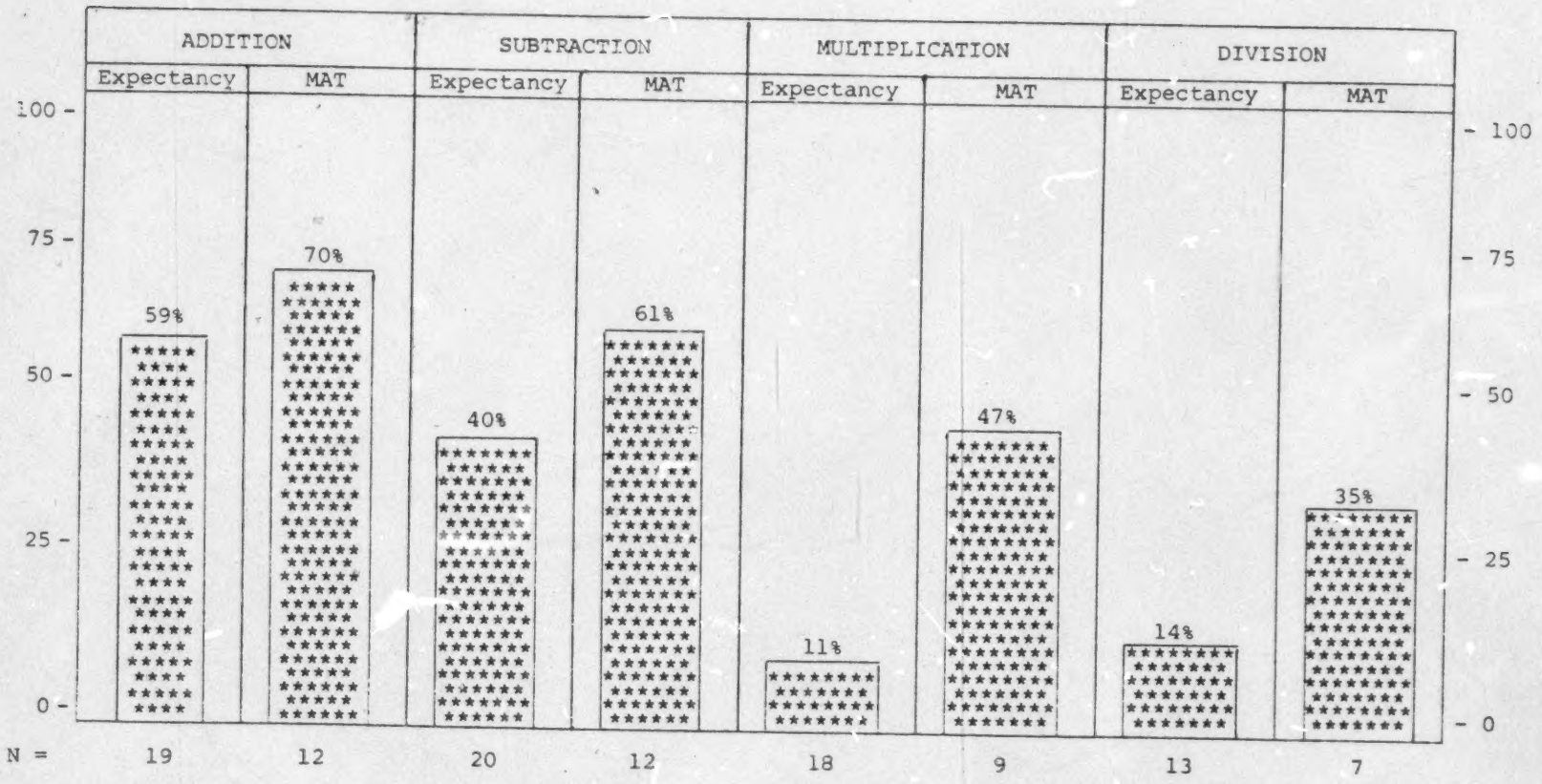
Only a small percent of the third grade students would have been introduced to multiplication and division skills. The more fundamental skills of addition and subtraction would have been encountered, but regrouping and the length of the problem are difficulty factors.

If, as the MAT results report, Salem students are a year behind in math computation skills, then their scores on the Math Expectancies are about where they should be. The Math Expectancies are expectancies equivalent to

GRAPH 1

Comparison of Percent Correct On Each Objective for the
Salem Math Expectancies and MAT-Computation Test

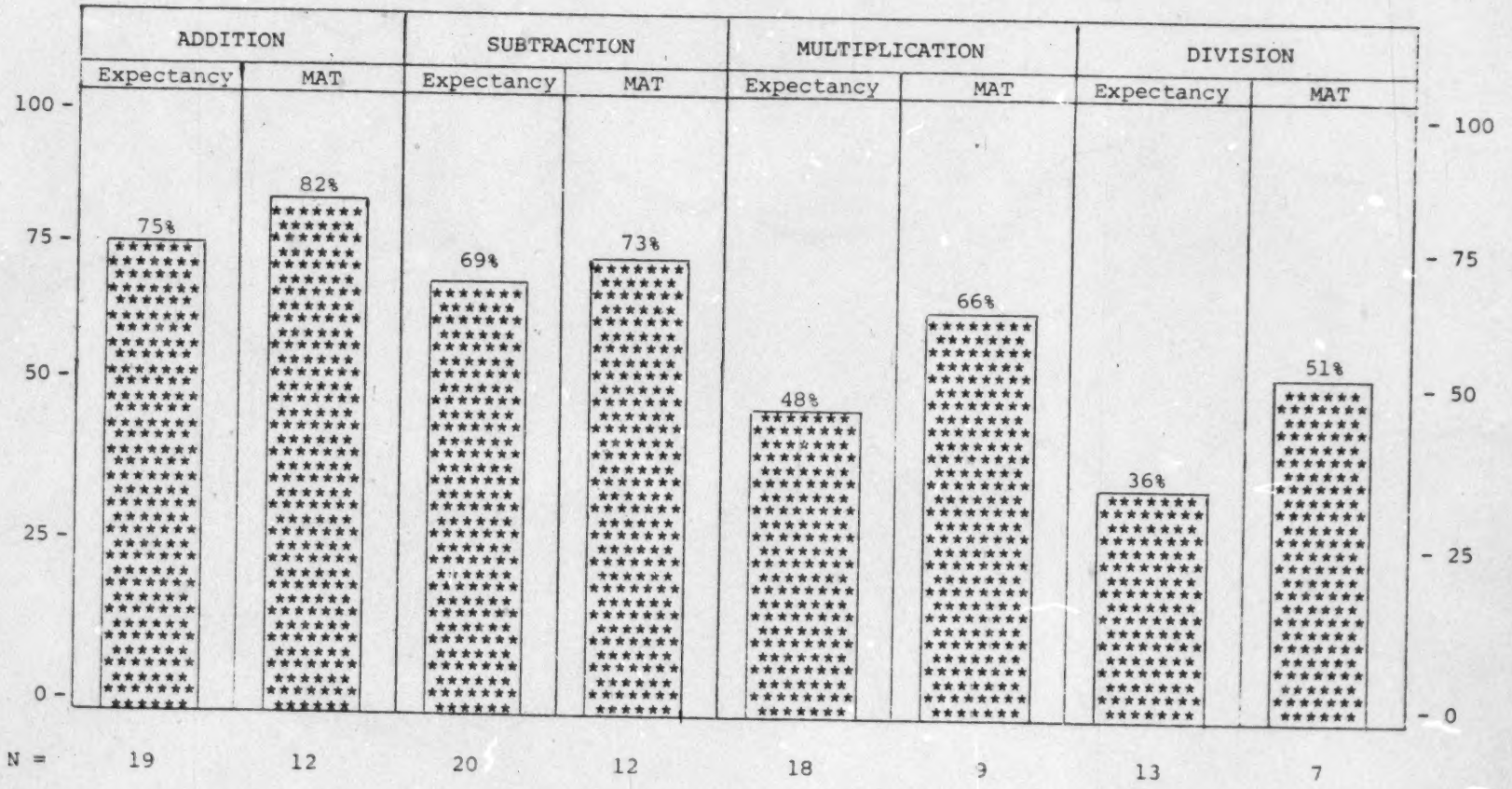
Grade 3



GRAPH 2

Comparison of Percent Correct on Each Objective for the
Salem Math Expectancies and MAT-Computation Test

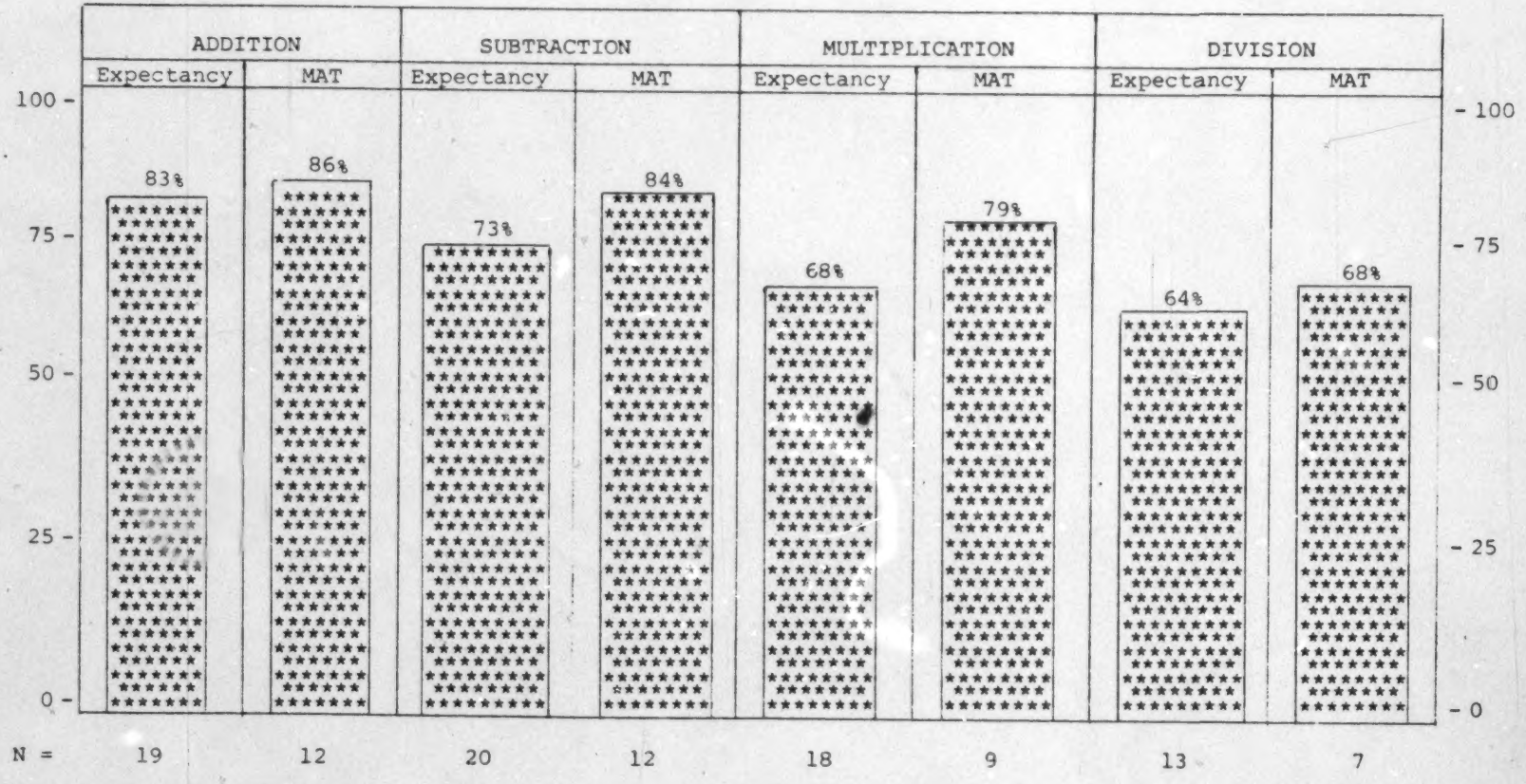
Grade 4



GRAPH 3

Comparison of Percent Correct on Each Objective for the
Salem Math Expectancies and MAT-Computation Test

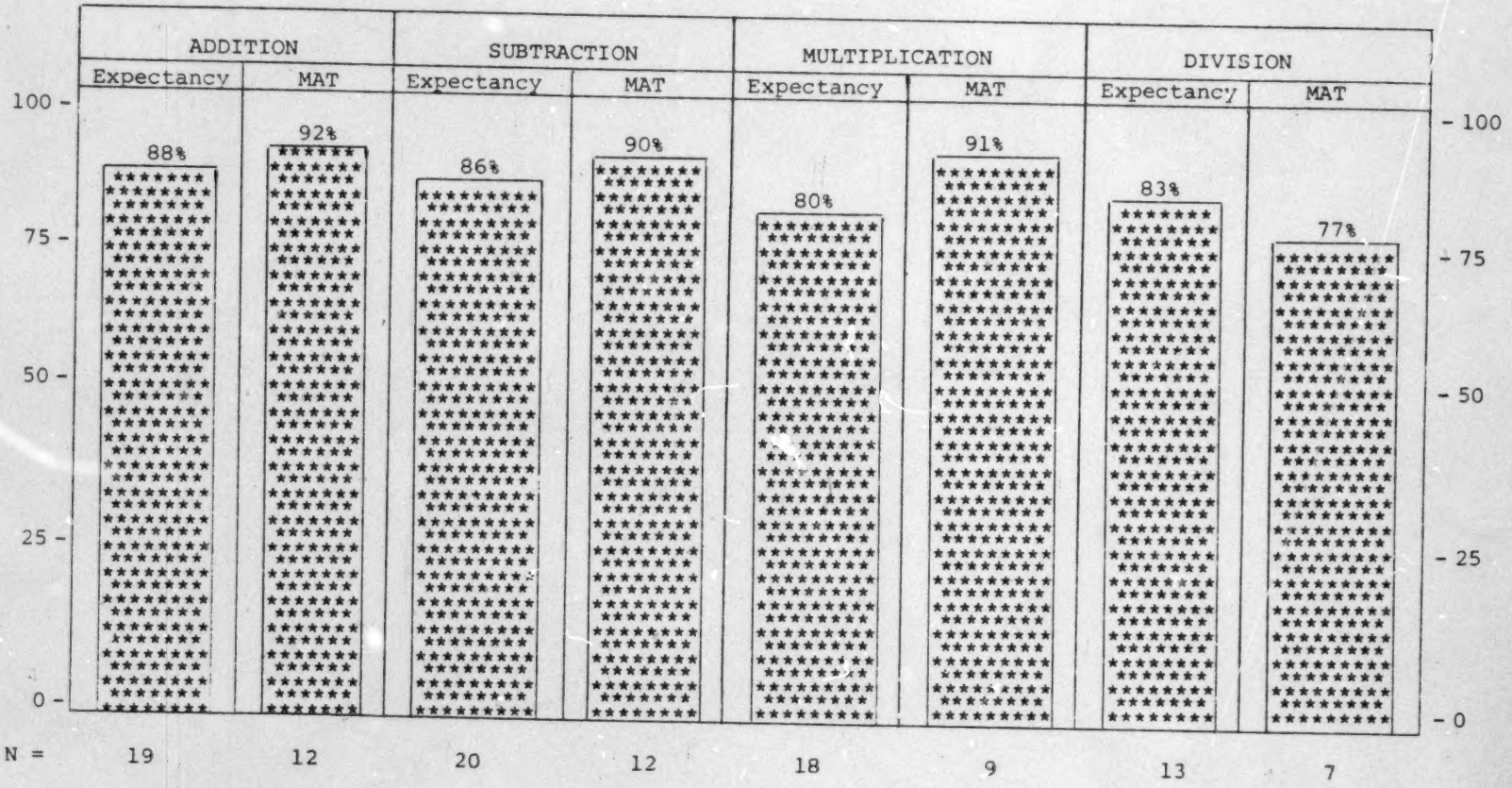
Grade 5



GRAPH 4

Comparison of Percent Correct on Each Objective for the
Salem Math Expectancies and MAT-Computation Test

Grade 6



what other districts have set for fourth grade students. They are also equivalent to fourth grade materials found in the majority of nationally developed math materials.

CONCLUSIONS

The following conclusions are drawn from the results of the study:

- The fourth grade addition expectancies were met by the end of the fifth grade.
- All other expectancies (subtraction, multiplication, and division) were met by the end of sixth grade.
- On the MAT - Computation Test (Grades 3.0-4.9), third graders scored approximately equal to national norms; fourth graders were at the 32nd percentile rank.
- By the end of fifth grade, Salem students were performing equal to the fourth-grade national average. This is one year behind where they would be expected.
- During the fourth grade, students made the greatest gains in addition and subtraction skills. At the fifth and sixth grade levels, the rate of gain tapered off drastically.
- During the fourth grade, students also made the greatest gain in multiplication skills. This gain continued to be substantial during the fifth and sixth grades.
- The greatest gain in division skills occurred during the fifth grade. The gain continued to be substantial during the sixth grade.

- The results show that the weakest skill is division on the Computation Test of the Metropolitan Achievement Test and multiplication on the Math Expectancies. However, the difference between mastery of multiplication and division skills on the Math Expectancy Test is minimal.
- For grades 3 through 5, the Metropolitan Computation Test was an easier test. By sixth grade, the two tests were of comparable difficulty.
- If each student is given the amount of time he or she needs, the majority will be able to master predefined skills.

IMPLICATIONS FOR TEACHERS

Since the evidence indicates our math expectancies (at least at level 4) are reasonable according to national norms, we can move ahead to implement them.

Teachers are encouraged to use the "Salem Math Expectancies," "The Math Materials Guides," and the accompanying tests to properly place students at a level at which they can be successful and to select assignment pages from the Houghton Mifflin Texts and other materials.

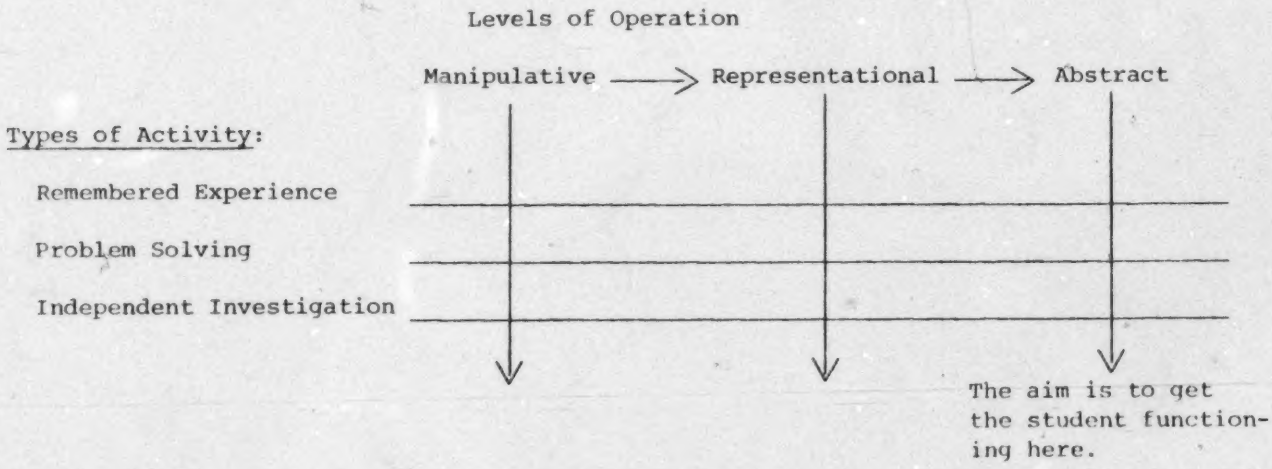
Teams are being trained from four elementary schools to explain use of these materials and suggest helpful Teaching Techniques. They worked together a week in August 1975 and now a "Math Expectancies Implementation Guide" is being prepared for their use. You may call upon them for help anytime after October 1, 1975.

The teams are: Candalaria: Jim Buck, Roberta Morgan, Elizabeth King,

Erma Hanna; Keizer: Dick Kemper, Judi Lawrence, John Wolf, Beverly Fitzgerald; Middle Grove: Joe Bowersox, Inez Gollersrud, and Dolores Morton; Wright: Dave Cronk, Gen Svendsen, and Mike Walsh.

What implication might be drawn from the evidence that third graders scored approximately equal to national norms, and that older students scored below norms. Does this mean the older students need more rote drill? Not necessarily. Research continues to show that rote drill is not very productive. Students quickly forget what they learn by rote. Helping most students to function at grade level gets harder each year if we follow only this path. Students must have a firm foundation of understanding numerical relationships discovered by working with concrete objects before they can remember abstract operations.

Bob Wirtz, author of a program gaining wide acceptance in Oregon, has developed a simple model showing the experiences children need to develop the ability to solve their own problems using abstract operations. They need to have experiences at each step in this model:



Manipulatives include counters (such as beans), Cuisenaire or other rods, geoboards, and abacuses.

Representational presentations include pictures of sets of objects, squared paper, arrays of dots, number lines, and hundreds boards. A meter stick makes an excellent number line on which groups of ten are easy to recognize. Money is sort of a representational manipulative.

If students use these materials to discover relationships, for themselves, whenever a new concept is approached, they will have a firm foundation for learning the abstract operations.

With this preparation, drill will be meaningful. Short, frequent periods of drill are essential to maintain skills and develop speed. However, carefully selected games are great for spicing up the drill now and then.

If each student is provided these varied opportunities at a level where he clearly has the prerequisite skills, progress should be optimum. But several closely related expectancies may be taught together in some cases to best utilize time and materials. Think of the expectancies as check points along the way to make sure no essential skills have been neglected, not as barriers which restrict the learning process.

APPENDIX A

APPENDIX A

Level Four

Mathematics Expectancies

I. Number Theory and Sequence

The child will be able to:

A. read numerals through six digits - 80% accuracy.

B. write numerals through six digits - 80% accuracy.

C. write signs for greater than, less than, or equal (>, <, =) when comparing numbers up to 1,000,000 - 80% accuracy.

II. Mathematical Operations

The child will be able to:

A. write the sums of 100 basic addition facts (0-9 in random order) in five minutes - 95% accuracy.

B. write the differences of the 100 basic subtraction facts in seven minutes - 95% accuracy.

C. add two 1-6 place numbers with random regrouping - 80% accuracy.

D. add four 1-3 place numbers in columns with random regrouping - 80% accuracy.

E. subtract 1-4 place numbers with random regrouping - 80% accuracy.

F. subtract 1-4 place numbers with random regrouping and zeros in the top and/or bottom number - 80% accuracy.

G. solve a variety of addition and subtraction problems with and without regrouping - 80% accuracy.

H. check subtraction problems by addition (NOTE: teachers may wish to approach this as one use of inverse operations) - 100% accuracy.

I. write the products of 100 multiplication facts through 9x9 in seven minutes - 97% accuracy.

J. multiply two, three and four digit numbers by one digit numbers with and without regrouping - 80% accuracy.

K. multiply two digit numbers by multiples of ten (example, 54x20) - 80% accuracy.

L. multiply two digit numbers by two digit numbers with regrouping - 60% accuracy.

M. write the quotients of 90 division facts (1's - 9's) in ten minutes using either or - 95% accuracy.

N. divide two digit by one digit numbers with and without a remainder - 80% accuracy. (NOTE: standard form is the end goal by fifth grade)

O. divide three digit by one digit numbers, with and without a remainder - 60% accuracy. (standard form is the end goal by fifth grade) NOTE: include both three digit quotients $3\overline{)999}$ and two digit quotients $3\overline{)108}$.

P. solve a variety of addition, subtraction, multiplication and division problems with and without regrouping - 60% accuracy.

Q. solve one-step story problems showing his/her work in equation and/or working form. (NOTE: These problems may be presented orally or in written form) - 80% accuracy.

III. Place Value

The child will be able to:

A. identify place value of all digits up to 1,000,000 - 80% accuracy.

B. write in expanded notation and in short form numbers up to 1,000,000. (example, expanded notation 600,000 + 70,000 + 6,000 + 300 + 40 + 5; short form 676,345) - 80% accuracy.

IV. Measurement

The child will be able to:

A. read a clock to the nearest minute in the form of 6:32 - 80% accuracy.

B. measure lengths to the nearest fourth inch - 80% accuracy.

C. interchange yards, feet and inches (3 yds., 9 ft., 108 in.) - 80% accuracy (use manipulative aids).

D. make change from $5 - 80% accuracy.

E. use dollar signs and decimal points when adding and subtracting amounts of money - 80% accuracy.

V. Fractions

The child will be able to:

A. name and write the fraction(s) when a shape or set is divided into twelve parts or less - 80% accuracy. NOTE: write fractions in this form not . This form is necessary for more advanced computation.

B. give equivalent fractions through twelfths when shown pictures, number lines, or using manipulative aids such as Cuisenaire Rods - 80% accuracy.